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Novel experimental constraints on forming iron-oxide apatite (IOA) deposits via magma–evaporite–FeP-rocks reaction

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Iron-oxide apatite (IOA) deposits host iron and could potentially supply rare earth elements[1,2], but their origin is controversial. For instance, the continental arc hosted El Laco deposit in Chile has been suggested to form via different ore-forming materials and processes, including iron-rich melts[3], magnetite-bubble flotation[4], iron-rich fluids[5], iron-rich sulfate/chloride liquids[3,6,7,10] or hydrothermal metasomatic of host rocks[8]. Reactions between the El Laco magmatic-hydrothermal system and underlying evaporites and FeP-rich rocks were also implicated in its formation[3,9], supported by studies indicating evaporite involvement in IOA formation[10,11]. However, previous experiments on IOA deposits did not assess evaporites in their compositions.

Hence, piston cylinder experiments were conducted to test the hypothesis that IOA deposits like El Laco formed via reactions between magma, FeP-rich strata, and sulfate-bearing evaporite layers. This involved reacting apatite, Fe-oxides, and synthetic evaporites (rich in SO_4^{2-}, Cl^-, CO_3^{2-}, and H_2O) with a synthetic intermediate silicate mix.

At experimental conditions (0.4 GPa, 1200–1000 °C), we observed desilication, Fe-Si immiscibility, Fe-bearing carbonate-sulfate liquids, Fe-bearing hydrothermal fluids, Fe-bearing hydrosaline chloride liquids, magnetite-bubble pair, and dendritic magnetite, demonstrating multiple ore formation materials and processes and supporting the above hypothesis. This indicates that any of the single previously proposed ore-forming materials only partially explain the IOA formation process, and suggests that their combined effect, derived from the inputs of sulfate-bearing evaporite into the magmatic system, is crucial for explaining IOA deposits, especially El Laco. In addition, the reaction increased SO_4^{2-}, Cl^-, and presumably CO_3^{2-} concentrations of silicate melts. These anions enhance the transportation and enrichment of various metals. These imply that surface-formed salty rocks (e.g., evaporites, carbonates), once buried or subducted, may serve as “salt feeders” to aid various salt liquids-related magmatic-hydrothermal ore formation upon later magmatic assimilation.

[1] Reich et al. (2022), NREE,3,758-775.
[2] Yan et al. (2024), GPL,32,14-20.
[3] Pietruszka et al. (2023), NC,14,8424.
[4] Ovalle et al. (2018), SR,8,14855.
[5] Ovalle et al. (2022), GCA,330,230-257.
[6] Zeng et al. (2024), SA,10,eadk2174.
[7] Bain et al. (2021), Geology,40,1044-1048.
[8] Sillitoe & Burrows (2002), EG,97,1101-1109.
[9] Tornos et al. (2024) MD,59,185-229.
[10] Xu et al. (2024), Geology,52,417-422.
[11] Barton & Johnson (1996), Geology,24,259-262.